

## Environmental Protection Agency

## § 1065.642

measurements and allowing more time for flows to stabilize.

(6) If the number of remaining  $C_d$  values is seven or greater, recalculate the mean and standard deviation of the remaining  $C_d$  values.

(7) If the standard deviation of the remaining  $C_d$  values is less than or equal to 0.3% of the mean of the remaining  $C_d$ , use that mean  $C_d$  in Eq. 1065.642-6, and use the CFV values only down to the lowest  $r$  associated with the remaining  $C_d$ .

(8) If the standard deviation of the remaining  $C_d$  still exceeds 0.3% of the mean of the remaining  $C_d$  values, repeat the steps in paragraph (e)(4) through (8) of this section.

[70 FR 40516, July 13, 2005, as amended at 73 FR 37326, June 30, 2008; 73 FR 59331, Oct. 8, 2008; 75 FR 23045, Apr. 30, 2010; 75 FR 68464, Nov. 8, 2010]

### § 1065.642 SSV, CFV, and PDP molar flow rate calculations.

This section describes the equations for calculating molar flow rates from various flow meters. After you calibrate a flow meter according to § 1065.640, use the calculations described in this section to calculate flow during an emission test.

(a) *PDP molar flow rate.* Based upon the speed at which you operate the PDP for a test interval, select the corresponding slope,  $a_1$ , and intercept,  $a_0$ , as calculated in § 1065.640, to calculate molar flow rate,  $\dot{n}$  as follows:

$$\dot{n} = f_{\text{nPDP}} \cdot \frac{p_{\text{in}} \cdot V_{\text{rev}}}{R \cdot T_{\text{in}}} \quad \text{Eq. 1065.642-1}$$

Where:

$$V_{\text{rev}} = \frac{a_1}{f_{\text{nPDP}}} \cdot \sqrt{\frac{p_{\text{out}} - p_{\text{in}}}{p_{\text{out}}}} + a_0 \quad \text{Eq. 1065.642-2}$$

*Example:*

$a_1 = 50.43 \text{ (m}^3\text{/min)} = 0.8405 \text{ (m}^3\text{/s)}$   
 $f_{\text{nPDP}} = 755.0 \text{ rev/min} = 12.58 \text{ rev/s}$   
 $p_{\text{out}} = 99950 \text{ Pa}$   
 $p_{\text{in}} = 98575 \text{ Pa}$

$a_0 = 0.056 \text{ (m}^3\text{/rev)}$   
 $R = 8.314472 \text{ J/(mol} \cdot \text{K)}$   
 $T_{\text{in}} = 323.5 \text{ K}$   
 $C_p = 1000 \text{ (J/m}^3\text{)/kPa}$   
 $C_t = 60 \text{ s/min}$

$$V_{\text{rev}} = \frac{0.8405}{12.58} \cdot \sqrt{\frac{99950 - 98575}{99950}} + 0.056$$

$V_{\text{rev}} = 0.06383 \text{ m}^3\text{/rev}$

$$\dot{n} = 12.58 \cdot \frac{98575 \cdot 0.06383}{8.314472 \cdot 323.5}$$

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$\dot{n} = 29.428 \text{ mol/s}$

(b) *SSV molar flow rate.* Based on the  $C_d$  versus  $Re^\#$  equation you determined

according to §1065.640, calculate SSV molar flow rate,  $\dot{n}$  during an emission test as follows:

$$\dot{n} = C_d \cdot C_f \cdot \frac{A_t \cdot p_{in}}{\sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}} \quad \text{Eq. 1065.642-3}$$

*Example:*

$A_t = 0.01824 \text{ m}^2$   
 $p_{in} = 99132 \text{ Pa}$   
 $Z = 1$   
 $M_{mix} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$   
 $R = 8.314472 \text{ J/(mol}\cdot\text{K)}$   
 $T_{in} = 298.15 \text{ K}$   
 $Re^\# = 7.232 \cdot 10^5$   
 $\gamma = 1.399$

$\beta = 0.8$   
 $\Delta p = 2.312 \text{ kPa}$   
 Using Eq. 1065.640–7,  
 $r_{ssv} = 0.997$   
 Using Eq. 1065.640–6,  
 $C_f = 0.274$   
 Using Eq. 1065.640–5,  
 $C_d = 0.990$

$$\dot{n} = 0.990 \cdot 0.274 \cdot \frac{0.01824 \cdot 99132}{\sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 298.15}}$$

$\dot{n} = 58.173 \text{ mol/s}$

(c) *CFV molar flow rate.* Some CFV flow meters consist of a single venturi and some consist of multiple venturis, where different combinations of venturis are used to meter different flow rates. If you use multiple venturis and you calibrated each venturi independently to determine a separate discharge coefficient,  $C_d$ , for each venturi, calculate the individual molar flow rates through each venturi and sum all their flow rates to determine  $\dot{n}$ . If you use multiple venturis and you calibrated each combination of venturis,

calculate  $\dot{n}$  as using the sum of the active venturi throat areas as  $A_t$ , the square root of the sum of the squares of the active venturi throat diameters as  $d_t$ , and the ratio of the venturi throat to inlet diameters as the ratio of the square root of the sum of the active venturi throat diameters,  $d_t$ , to the diameter of the common entrance to all of the venturis,  $D$ . To calculate the molar flow rate through one venturi or one combination of venturis, use its respective mean  $C_d$  and other constants you determined according to §1065.640 and calculate its molar flow rate  $\dot{n}$  during an emission test, as follows:

$$\dot{n} = C_d \cdot C_f \cdot \frac{A_t \cdot p_{in}}{\sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}} \quad \text{Eq. 1065.642-4}$$

*Example:*

$C_d = 0.985$   
 $C_f = 0.7219$   
 $A_t = 0.00456 \text{ m}^2$   
 $p_{in} = 98836 \text{ Pa}$   
 $Z = 1$   
 $M_{mix} = 28.7805 \text{ g/mol} = 0.0287805 \text{ kg/mol}$

$R = 8.314472 \text{ J/(mol}\cdot\text{K)}$   
 $T_{in} = 378.15 \text{ K}$

$$\dot{n} = 0.985 \cdot 0.7219 \cdot \frac{0.00456 \cdot 98836}{\sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 378.15}}$$

$$\dot{n} = 33.690 \text{ mol/s}$$

[75 FR 23047, Apr. 30, 2010, as amended at 75 FR 68464, Nov. 8, 2010]

#### § 1065.644 Vacuum-decay leak rate.

This section describes how to calculate the leak rate of a vacuum-decay leak verification, which is described in § 1065.345(e). Use Eq. 1065.644-1 to calculate the leak rate,  $\dot{n}_{\text{leak}}$ , and compare it to the criterion specified in § 1065.345(e).

$$\dot{n}_{\text{leak}} = \frac{V_{\text{vac}}}{R} \cdot \frac{\left( \frac{p_2}{T_2} - \frac{p_1}{T_1} \right)}{(t_2 - t_1)} \quad \text{Eq. 1065.644-1}$$

Where:

$V_{\text{vac}}$  = geometric volume of the vacuum-side of the sampling system.

$R$  = molar gas constant.

$p_2$  = Vacuum-side absolute pressure at time  $t_2$ .

$T_2$  = Vacuum-side absolute temperature at time  $t_2$ .

$p_1$  = Vacuum-side absolute pressure at time  $t_1$ .

$T_1$  = Vacuum-side absolute temperature at time  $t_1$ .

$t_2$  = time at completion of vacuum-decay leak verification test.

$t_1$  = time at start of vacuum-decay leak verification test.

Example:

$$V_{\text{vac}} = 2.0000 \text{ L} = 0.00200 \text{ m}^3$$

$$R = 8.314472 \text{ J/(mol} \cdot \text{K)}$$

$$p_2 = 50.600 \text{ kPa} = 50600 \text{ Pa}$$

$$T_2 = 293.15 \text{ K}$$

$$p_1 = 25.300 \text{ kPa} = 25300 \text{ Pa}$$

$$T_1 = 293.15 \text{ K}$$

$$t_2 = 10:57:35 \text{ AM}$$

$$t_1 = 10:56:25 \text{ AM}$$

$$\dot{n}_{\text{leak}} = \frac{0.0002}{8.314472} \cdot \frac{\left( \frac{50600}{293.15} - \frac{25300}{293.15} \right)}{(10:57:35 - 10:56:25)}$$

$$\dot{n}_{\text{leak}} = \frac{0.00200}{8.314472} \cdot \frac{86.304}{70}$$

$$\dot{n}_{\text{leak}} = 0.00030 \text{ mol/s}$$

[73 FR 37327, June 30, 2008]

#### § 1065.645 Amount of water in an ideal gas.

This section describes how to determine the amount of water in an ideal gas, which you need for various performance verifications and emission calculations. Use the equation for the vapor pressure of water in paragraph (a) of this section or another appropriate equation and, depending on whether you measure dewpoint or relative humidity, perform one of the cal-

culations in paragraph (b) or (c) of this section.

(a) *Vapor pressure of water.* Calculate the vapor pressure of water for a given saturation temperature condition,  $T_{\text{sat}}$ , as follows, or use good engineering judgment to use a different relationship of the vapor pressure of water to a given saturation temperature condition:

(1) For humidity measurements made at ambient temperatures from (0 to 100) °C, or for humidity measurements